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Implementing spirometry and fractional exhaled nitric oxide testing in childhood asthma management in UK primary care: an observational study to examine training and implementation cost and impact on patient's health use and outcome

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ABSTRACT

Objectives Implementation of guidelines into clinical practice is challenging and complex. This study aims to (1) identify the training needs and capacity requirements, and (2) explore the impact on healthcare utilisation and asthma-related quality of life of implementing both spirometry and fraction of exhaled nitric oxide in diagnosis of asthma among children in the UK primary care.

Methods Ten UK general practitioner practices and a total of 612 children (5–16 years) with diagnosed or suspected asthma were invited to participate in this prospective observational study. The total times that the trainer and trainee clinical staff spent on developing the training package, providing and receiving, and performing and interpreting the two tests as part of routine child asthma review were collected, and costs were calculated. We compared healthcare utilisation and asthma-related and general health-related quality of life data between the 6 months before and after the asthma review guided by objective tests.

Results The average training cost for the 27 primary care clinical members was £1395. The average cost to implement and deliver the test-guided asthma review among the 612 included children was £22. In the 6 months following the tests-guided asthma review, both unplanned primary care attendance, and hospital admissions were reduced, and the asthma-related health status increased significantly.

Conclusion This study provides robust cost estimates of the resources needed to implement the National Institute for Health and Care Excellence asthma guideline. It also demonstrates the potential to save healthcare costs and improve health status among asthmatic children by implementing this guideline.

What is already known on this topic?

- Clinical guidelines are more likely to be adopted with strong professional support, a convincing evidence base and no unfunded costs.
- Investment in training and additional equipment are needed to implement the asthma guideline in primary care.

What this study adds?

- This study quantified the training, support, and associated resources and costs needed to implement National Institute for Health and Care Excellence clinical guidelines in real clinical setting.
- This study showed that with sufficient training of existing clinical staff, it is feasible to adopt the lung function tests in primary care.
- The guideline is acceptable to clinicians, patients and carers and yields identifiable health benefits to many children with asthma.

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INTRODUCTION

In the UK and elsewhere in the world, organisations such as the UK National Institute for Health and Care Excellence (NICE) publish large amounts of evidence-based recommendations on how health professionals and service commissioners should care for patients in general practitioner (GP) surgeries and hospitals. Due to local variation in epidemiological and social needs as well as the supporting structures, implementation of guidance into clinical practice is challenging and complex.

In November 2017, NICE published clinical guidelines on asthma and recommended the use of spirometry and fraction of exhaled nitric oxide (FeNO) testing for diagnosis and management in both adults and children. A prospective observational cohort study, the Childhood Asthma Management in Primary Care: Implementation of Exhaled Nitric Oxide and Spirometry Testing (CHAMPIONS), has been conducted to identify the training needs and capacity requirements of UK primary care practices in order for objective lung function testing to be made available for children with suspected or an existing diagnosis of asthma cared for in the non-hospital setting.[1]

Here we report the costs associated with implementation of spirometry and FeNO testing for children in primary care. We calculate the extra resources needed to deliver spirometry and FeNO testing as part of asthma reviews in children

managed in primary care. Furthermore, we describe how the experimental implementation of spirometry and FeNO impacted on children's asthma quality of life scores, asthma control status and healthcare use.

METHODS

CHAMPIONS study: a brief summary

CHAMPIONS was a prospective observational cohort study conducted in 10 general practices in the East Midlands, UK, between 2016 and 2017 designed to evaluate the implementation and clinical outcomes related to the delivery of spirometry and FeNO testing for children with diagnosed or suspected asthma in primary care.[2]

A package of training (teaching and practical) was delivered to 27 nurse practitioners, practice nurses and healthcare assistants in primary care. They then went on to perform asthma review and tests in children independently following the training.

Children aged 5–16 years on the practice asthma register and children with suspected asthma, not on the asthma register but who, in the previous 12 months, were prescribed asthma medications were invited for a routine asthma review by the practice staff.

Data pertaining to training delivery, time to complete training and the test and clinical outcome data observed in this study have been published elsewhere.[1 2]

Data collection

Children and their carers were asked to complete three questionnaires during their asthma review (baseline) and were contacted again to fill in the same questionnaires 6 months after the review.

- *Asthma Control Test (ACT)* was used to assess children's asthma control status: younger children (4–11 years, CACT with seven questions with support from their parents or carers)[3] and older children (12–16 years, ACT with five questions).[4]
- *Mini Paediatric Asthma Quality of Life Questionnaire (mini-PAQLQ)* was used to assess children's asthma-related quality of life.[5]
- *Child's Health Utility 9D (CHU9D):was used to assess* children's general health status.[6 7]

Healthcare utilisation

Healthcare utilisations data for the 6 months before and after the asthma review were extracted from the GPs' electronic clinical records. These included unplanned GP/emergency department visits and hospital admissions (stay more than 1 day day), and main asthma medications prescribed.

Data analysis

Education and training costs

We calculated the total time the members of the clinical team spent on developing and implementing the CHAMPIONS training package. The training package consisted of two parts: (1) 2-hour face-to-face teaching and (2) practical spirometry and FeNO training, and was delivered by the trainers (ie, the respiratory clinical fellow and/or research nurse) to trainees individually or to small groups of trainees. We identified salary bands and hourly costs for members of the clinical team and calculated the total costs of delivering the paediatric training package.

Implementation and test delivery costs

Children identified from the practice databases were invited to attend a designated children's asthma review clinic. Asthma review clinics were all led by a clinical member of the practice staff. The trainer research team attended all clinics to support spirometry and FeNO training, and for data collection purposes only.

Healthcare utilisation

Standard unit cost for each GP visit was obtained from Unit Costs of Health and Social Care (Personal Social Services Research Unit) 2017. Standard unit cost for hospitalisation was obtained from NHS reference cost 2017 by averaging hospital admission costs for three relevant Healthcare Resource Group codes due to children's asthma in 2017. Average unplanned GP visits and hospital admissions were calculated. Given the non-normal distribution of the data, the Wilcoxon signed-rank test was used to examine differences of median GP visits and hospital admissions between the two time periods. Combined with standardised unit costs, the differences between total costs and mean costs between the two time periods were calculated.

Data on asthma medication prescriptions were collected for the two time periods and were presented as per child median (IQR) and mean doses or numbers of asthma medication inhalers prescribed, as well as the frequencies and percentages of children within a range of does categories. Wilcoxon signed-rank test was used to examine differences in medication usage between the two time periods.

Asthma control status and general health status

We assessed the asthma control status of each child using ACT and CACT. Their asthma-related quality of life was assessed using the mini PAQLQ, and general health-related quality of life was assessed using the CHU9D. The baseline data of ACT and CACT, miniPAQLQ and CHU9D were collected when the children attended their asthma review. The children or their carers completed the questionnaires. They were asked to fill in and post back their questionnaires 6 months following their asthma review. The mean scores of each questionnaire at baseline and follow-up were calculated and compared using paired t-test, given the normal distribution of the data.

RESULTS

Education and practical training costs

The standard unit costs for clinical staff in primary care who received training and for the research team who developed and delivered the training can be found in online supplemental appendix 1.

Development of the paediatric spirometry and FeNO tests training package

A total of £4328 was estimated to cover the clinicians' time spent on the development of the training package (see online supplemental appendix 2 for details)

Delivery of the paediatric spirometry and FeNO tests training package

Part 1: Two-hour face-to-face teaching

A total of £3290 was estimated for both the trainers' and the trainees' time spent on delivering and receiving the 2-hour face-to-face training (see online supplemental appendix 3 for details).

Part 2: Practical training at GP surgeries

The clinical trainees' times spent on observing the process, performing and interpreting the tests under supervision were combined with the standard unit costs and resulted in a total

Table 1 Key costs to implement National Institute for Health and Care Excellence asthma guideline

	Total working hours	Total costs (£)
Development of the training package	74	4328
Face-to-face teaching	79	3290
Practice training and performing asthma tests	978	36 949
Trainees to implement and deliver test-guided asthma review	289	11 479
Testing machines (two spirometers)	–	2271

The total working hours add various clinical staff's time together, but they have different unit costs.

cost of £6898. Meanwhile, the trainers presented at 147 training clinics, and each clinic lasted 3 hours, which resulted in 441 hours spent on delivering the practical training sessions and a total cost of £23 153. When the costs of both the trainers and trainees were combined, the total sum of the practice training was £30 051.

The total cost of face-to-face teaching and practice training was £33 341. The total costs for training development and delivery were £37 669, and the average cost per staff member trained was £1395 (n=27) (see online supplemental appendix 3 for details).

Implementing and delivering costs

A total of £11 479 was estimated as the costs of trainees' (GP clinical staff) time spending on delivery of the test-guided asthma reviews. These included their time receiving practical training as well as on independently performing and interpreting tests results and conducting asthma reviews. Given these costs also included trainees' costs for practical training of £6898, an estimated £4581 was costed for the primary care staff to independently deliver the test-guided asthma review to a subgroup of children in the sample.

The CHAMPION team bought two spirometry machines for the study and was given two FeNO machines which they rotated between all 10 GP practices. In reflecting what happened in the study, a total of £2271 was therefore added as the costs of the testing equipment (an average of £3.7 per child).

In the CHAMPIONS study, the total costs of implementing and delivering the test-guided asthma reviews for the 612 children were £13 750, and the average cost per child was £22.

Table 1 summarises key components of the costs to implement NICE asthma guideline in the CHAMPIONS study.

Health care utilisation costs before and after the test-guided asthma reviews

In total, 612 children responded to the written invitations and attended clinics held between June 2016 and August 2017; of these, 456 (75%) were on the practice asthma registers. Sixty-three per cent of the children were recruited in the months of March–August, and the remainder was recruited in the months of September–February.

As shown in table 2, the average number of unplanned healthcare attendance, including GP and walk-in centre visits, A&E attendances, hospital admissions and associated NHS costs all decreased significantly during the 6-month period after the test-guided asthma review. The standard unit cost of £37 per GP visit was used for each unplanned healthcare attendance as no detailed data on different types of healthcare attendance were extracted. A total NHS cost saving of £26 064 and an average of £43 saving per child were estimated on the decrease of unplanned GP visits and hospital admission for this sample.

In terms of asthma medications (table 3), the proportion of children prescribed at least one course of OCS fell from 11% to 6% at follow-up (p=0.007). There was an overall increase in the mean daily inhaled corticosteroids (ICS) dose prescribed per patient at follow-up. This was due to a trend towards fewer children not being prescribed ICS, and a corresponding increase in those prescribed between 200 and 400 mcg beclomethasone equivalent per day of ICS. There was also an increase in the number of ICS inhalers prescribed per patient at follow-up (p<0.001). There was no significant difference observed in the number of short-acting inhaled beta agonist inhalers prescribed in the 6 months before and after the asthma reviews.

Asthma control status and general health status

Data on asthma-related quality of life were collected from all children recruited at baseline (n=612), but only 226 (37%) provided their data at 6 months' follow-up (table 4). ACT scores in children aged 5–11 and ≥12 years improved significantly from baseline to follow-up. The overall score and individual subdomains of miniPAQLQ all increased although not statistically significant. On the other hand, the children's general health status declined significantly at follow-up.

DISCUSSION

CHAMPIONS is among the few studies to comprehensively identify and quantify the training, support and associated resources and costs needed to implement NICE clinical guidelines in real clinical setting. The research team developed and delivered a two-stage educational and practical training package of using the

Table 2 Mean (SD) of healthcare utilisation and medications usage and costs 6 months before and after test-guided asthma review at baseline

		6 months before asthma review (n=612)			6 months after asthma review (n=605)		
Healthcare visits	Unit cost	Events (n)	Usage mean per patient (SD)	Mean cost (£) (SD)	Events (n)	Usage mean per patient (SD)	Mean cost (£) (SD)
Unplanned healthcare attendance (p=0.003)*	£37 per GP visit	117	0.29 (0.64)	10.7 (23.56)	119	0.197 (0.48)	7.27 (17.79)
Unplanned hospital admission (p=0.008)*	£1069 per child hospital admission	14	0.02 (0.15)	24.45 (159.95)	4	0.007 (0.13)	7.07 (137.37)

Average costs for paediatric asthma hospital admission: PD12A (£1467), 12B (£954) and 12C (£787) (NHS reference cost 2017).
Mean (SD) are presented here. The median (range) unplanned healthcare attendance and unplanned hospital admission at both baseline and follow-up are 0 (0–0).
*P<0.05 (based on Wilcoxon signed-rank test).
GP, general practitioner.

Table 3 Asthma medication prescription 6 months before and after the test-guided asthma reviews

		6 months before asthma review (n=612)	6 months after asthma review (n=605)	P value
Number (%) of children prescribed ≥1 course of OCS		65 (10.6)	38 (6.3)	0.007*
Median (IQR) dose of daily prescribed ICS per child		200 (200–400)	200 (200–400)	<0.001*
Mean (SD) does of daily prescribed ICS per child		191.1 (218.9)	218.2 (213.3)	
Number (%) of children by daily prescribed ICS dose (mcg)	0	201 (33)	168 (28)	
	>0–200	270 (44)	253 (42)	
	>200–400	120 (20)	160 (26)	
	>400	21 (3)	24 (4)	
Median (IQR) number of preventer inhalers prescribed per child		2 (1–3)	2 (1–4)	<0.001*
Mean (SD) number of presenter inhalers prescribed per child		1.41 (1.73)	1.86 (1.97)	
Number (%) of children by number of preventer inhaler prescriptions issued	0	281 (46)	196 (32.4)	
	1–2	190 (31)	224 (37)	
	3–4	94 (15)	123 (20.3)	
	≥5	47 (8)	62 (10.3)	
Median (IQR) number of salbutamol inhalers prescribed per child		1 (0–3)	2 (1–3)	0.511
Mean (SD) number of Salbutamol inhalers prescribed per child		1.77 (1.98)	1.83 (1.97)	
Number (%) of children by number of SABA inhaler prescriptions	0	180 (29)	183 (30)	
	1–2	276 (45)	252 (42)	
	3–4	91 (15)	104 (17)	
	≥5	65 (11)	66 (11)	

*P<0.05.
ICS, inhaled corticosteroids; OCS, oral corticosteroids; SABA, short-acting inhaled beta agonist.

spirometry and FeNO tests to guide children's asthma diagnosis and management in primary care setting as recommended by NICE. The study further evaluated whether and to what extent the test-guided asthma reviews impacted on health service usage and patient's health outcomes.

Using our approach, we calculated that an average cost of £77 (total cost of £46 838) per child patient is needed for the overall implementation of the test-guided asthma review. This includes £73.3 per child for clinical staff time spending on the development, delivery and acceptance of training and £3.7 for purchase of the equipment.

In this pragmatic study, the key driver of the implementation cost was the trainers' time spent on delivering the practical training at an average cost of £857.5 per trainee or £37.8 per child and £23 153 in total. These costs covered the trainers' time spent on delivery of training but did not include other costs such as travel time. Therefore, the real costs may be slightly underestimated. On the other hand, and importantly, the trainers' training time was estimated as all their time spent at the GP surgeries even though they were not actively providing training all the time. This suggests that the practical training sessions could be organised and managed in a more efficient way.

Table 4 Asthma control status and general health status at baseline and at 6 months' follow-up note

Mean ACT (SD) (n=79)	19.9 (4.0)	21.0 (3.8)	0.02*
Mean CACT (SD) (n=147)	20.8 (4.2)	22.1 (3.9)	0.001*
Mean CHU9D (SD)	0.88 (0.16)	0.85 (0.18)	0.007*
Mean PAQLQ Overall Score (SD)	5.92 (1.06)	6.02 (1.04)	0.199
Mean PAQLQ Activity Score (SD)	5.68 (1.31)	5.85 (1.22)	0.096
Mean PAQLQ Symptom Score (SD)	5.95 (1.18)	6.05 (1.17)	0.241
Mean PAQLQ Emotional Score (SD)	6.05 (1.08)	6.12 (1.08)	0.388

Analysis is limited to children with complete questionnaire data only at baseline and follow-up (n = 226).
*P<0.05.
ACT, Asthma Control Test; CHU9D, Child's Health Utility 9D; PAQLQ, Paediatric Asthma Quality of Life Questionnaire.

In terms of equipment costs, the CHAMPIONS team bought two spirometers for the study and was given two FeNO machines that they rotated between all 10 GP practices. This results in a very low equipment cost of a total of £2271 and an average of £3.7 per child. In a real-world situation, if GP surgeries invest in their own equipment, for example, one spirometer and one FeNO machine per practice, this will push the equipment costs up significantly. Following the equipment costs suggested by NICE, the estimated equipment and consumable costs could be as high as £22 535 and an average of £37 per child. The costs would include £17 947 for 10 spirometers and 10 calibration syringes as capital investment as well as running costs for 612 tests, comprising £606 for filters and £3982 for FeNO tests, including the failed and unsuccessful attempts. On the other hand, GPs could use the same equipment to manage adults with asthma.

It is worth noting that both the training costs and the equipment costs are one off capital costs, and the average costs would decrease following the implementation of the test-guided asthma review to more children. Testing hubs sharing equipment and staff between several GP surgeries would also reduce cost.

Unplanned healthcare attendances and hospital admissions reduced significantly after the test-guided review and based on the data would save the NHS an estimated £42.5 per child reviewed. More salbutamol, more corticosteroid inhalers and more other asthma preventers were prescribed but the number of children prescribed more than one course of OCS decreased. The cost implication was not clear without detailed information of prescriptions. In terms of impact on health outcomes, the children's asthma control status and asthma-related health state improved while their general health status declined. This is not expected and may be biased by the fact that only 37% (n=226) of participants had quality of life data at follow-up. This may also be due to the fact that improvements in asthma-specific

symptoms may not be reflected or captured by general health-related measures such as CHU9D.

CONCLUSION

Although it is widely recognised that implementation of clinical guidelines is difficult, little is known about successful and cost effective implementation strategies in primary care setting.[8 9] This study examined the support and associated NHS costs needed to implement the specific NICE clinical guidelines and the impact of implementation by comparing healthcare usage before and after the enhanced asthma review. Given the study design was an observational before and after comparison study, and the nature of staff involvement in the CHAMPION study, the impact of the intervention on medication prescriptions, healthcare usage and health status could have resulted by chance. Nevertheless, this study contributes to the wider literature of economic evaluation of guideline implementation strategies especially in primary care, which is an understudied area of research. More importantly, based on a real-life clinical setting, this study provides robust cost estimates to local and national decision makers of the resources needed for implementing this particular guideline. Modified implementation strategies could be adapted to be more cost-effective at a local or national level. This study also showed that, with sufficient training of existing practice staff, it is feasible to adopt spirometry and FeNO testing in primary care in a way that is acceptable to patients and carers and yields identifiable health benefits to many children with asthma.

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